# SIPHONAPTERA COLLECTED FROM MOLES AND THEIR NESTS AT WILP, NETHERLANDS, BY JHR. W. C. VAN HEURN



BY

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During a period of eleven years, from 1950 to 1960 inclusive, Jonkheer Drs. W. C. VAN HEURN collected well over a thousand specimens of the common European mole, *Talpa europaea* L., in the grounds of his estate "Kleine Noordijk" at Wilp, Gelderland, Netherlands. Apart from attempting to decrease the local population density of the mole (which is apparently most difficult to achieve), one of the main purposes of this mass collecting was a study of the variation in pelage (*cf.* W. C. van Heurn & A. M. Husson, 1959, *Zool. Bijdr. Leiden,* vol. 4, p. 1—16). Shortly after having started the trapping of moles, Jhr. VAN HEURN most kindly began to preserve for me the ectoparasites which he found on them. From May 1950 onwards all moles were collected from the traps with the least possible delay, wrapped up and subsequently searched for ectoparasites which were removed, without previous fumigation, by combing and brushing the host over a deep bowl. For each mole the sex and age, as well as the number of fleas removed, were recorded; all records were listed per month and the fleas collected in one month were put together in one tube.

Since a comparison of the composition of the flea fauna of the bodies of moles with that of moles' nests from the same area was thought to be of interest, Jhr. VAN HEURN most kindly and energetically also dug up 45 nests from which he collected the fleas.

I am deeply indebted to Jhr. VAN HEURN for collecting numerous fleas — not only from moles — in his characteristic meticulous manner over a long period of years.

## DESCRIPTION OF TRAPPING AREA

The estate "Kleine Noordijk" is situated 2 KM south of Twello and about 3 KM west of Wilp [viz., at 52° 13′ N. 6° 07′ E], in the province of Gelderland, Netherlands. The estate consists of woodland and meadows; the moles were caught in an area of approximately 10 hectares in which woodland dominates. The majority of moles, however, were trapped in an area of about 3 or 4 hectares in the wood adjoining the mansion.

## NUMBERS AND SPECIES OF FLEAS COLLECTED

A total of 13,330 fleas was collected: 12,058 from 1,005 (436 ♂, 569 ♀)

moles (average: 12 fleas per mole), 1,272 from 45 moles' nests (average: 28 fleas per nest). The numbers per species of fleas are given in Table I.

TABLE I

| Species of flea | From 1.005 moles | | | From 45 nests | | |
|---|---|---|---|---|---|---|
| | ♂ | ♀ | total | ♂ | ♀ | total |
| *P. minor* | 5.134 | 5.600 | 10.734 | 21 | 36 | 57 |
| *C. bisoctodentatus heselhausi* | 119 | 172 | 291 | 309 | 502 | 811 |
| *H. talpae talpae* | 84 | 77 | 161 | 30 | 67 | 97 |
| *C. agyrtes smitianus* | 312 | 514 | 826 | 100 | 174 | 274 |
| *P. soricis soricis* | 14 | 12 | 26 | | | |
| *D. dasycnema dasycnema* | 2 | 4 | 6 | | | |
| *M. penicilliger mustelae* | 6 | 4 | 10 | | | |
| *M. turbidus* | 4 | | 4 | | 1 | 1 |
| *C. assimilis* | | | | 1 | | 1 |
| *C. gallinae* | | | | 20 | 11 | 31 |
| Total | 5.675 | 6.383 | 12.058 | 481 | 791 | 1.272 |

Only two of the species of fleas collected are monoxenous parasites of *Talpa europaea*: *Palaeopsylla minor* (Dale) and *Ctenophthalmus bisoctodentatus heselhausi* (Oudemans). Of the other species, *Hystrichopsylla talpae talpae* (Curtis), *Ctenophthalmus agyrtes smitianus* Peus and *Ctenophthalmus assimilis* (Taschenberg) are primarily associated with small rodents, although they have in the mole a very suitable secondary host. The occurrence on moles of the remaining species is accidental: *Palaeopsylla soricis soricis* (Dale) and *Doratopsylla dasycnema dasycnema* (Rothschild) are parasites of shrews, *Malaraeus penicilliger mustelae* (Dale) and *Megabothris turbidus* (Rothschild) of microtine rodents, while *Ceratophyllus gallinae* (Schrank), being a bird-flea, is quite out of place in a mole's nest.

## MONTHLY TOTAL FLEA:MOLE INDICES

The term "total flea:mole index" — or in general: "total flea:host index" — simply means the average number of fleas of all species found per host individual. A "specific flea:host index" relates to the average number of a certain species of flea per host individual.

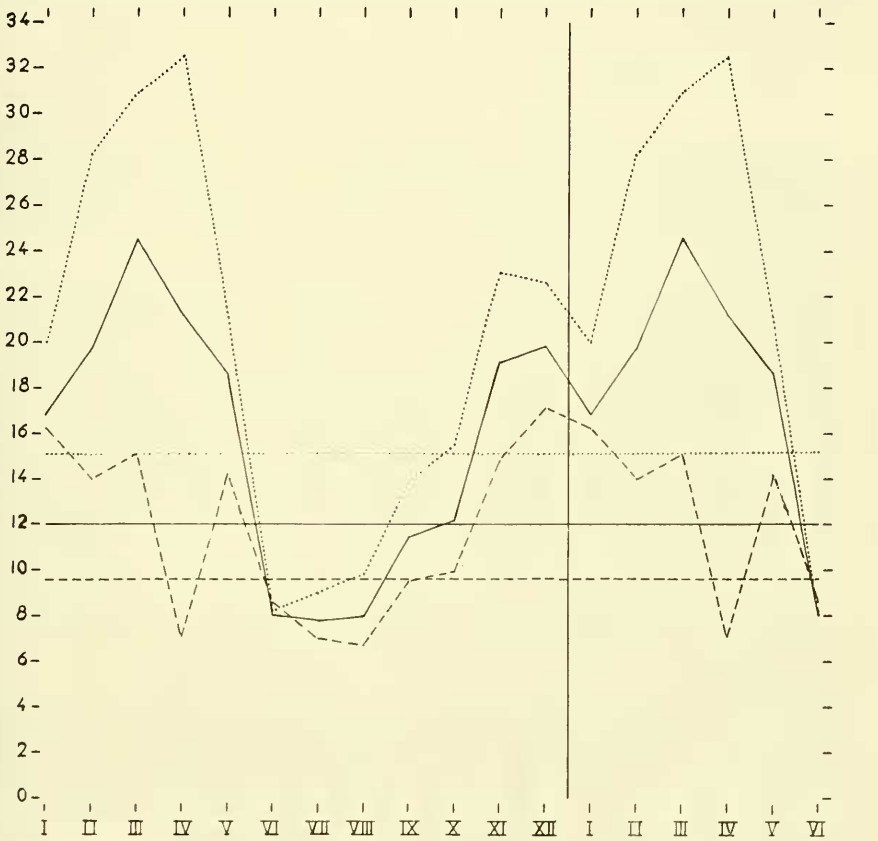
The monthly numbers of moles and fleas, as well as the total flea:mole index, are given in Table II. The numbers in brackets after the names of the months stand for the number of years during which collections were made in the given month.

It should be noted that the samples for the first four months of the year are relatively small and it is evident from the graphs (Graphs 1—6) that the figures for these months cannot be considered to be normal averages.

Plotting the figures of the monthly total flea indices in a graph (Graph 1 — the unbroken line), we see that the population of adult fleas is lowest during the summer months and highest during the winter. There is a remarkably sharp drop in numbers from May to June; this would indicate that either (a) the fleas quite

Table II

| Months | | No. of moles ♂ | No. of moles ♀ | No. of moles total | No. of fleas per ♂ mole | No. of fleas per ♀ mole | No. of fleas total | total flea:mole index per ♂ mole | total flea:mole index per ♀ mole | total flea:mole index total |
|---|---|---|---|---|---|---|---|---|---|---|
| January | (2) | 1 | 5 | 6 | 20 | 81 | 101 | 20.0 | 16.2 | 16.8 |
| February | (3) | 4 | 6 | 10 | 113 | 84 | 197 | 28.2 | 14.0 | 19.7 |
| March | (4) | 13 | 9 | 22 | 402 | 136 | 538 | 30.9 | 15.1 | 24.5 |
| April | (6) | 10 | 8 | 18 | 325 | 57 | 382 | 32.5 | 7.1 | 21.2 |
| May | (5) | 19 | 11 | 30 | 401 | 156 | 557 | 21.1 | 14.2 | 18.6 |
| June | (11) | 41 | 91 | 132 | 337 | 781 | 1.118 | 8.2 | 8.6 | 8.0 |
| July | (11) | 70 | 98 | 168 | 631 | 689 | 1.320 | 9.0 | 7.0 | 7.8 |
| August | (10) | 77 | 101 | 178 | 754 | 681 | 1.435 | 9.8 | 6.7 | 8.0 |
| September | (9) | 60 | 77 | 137 | 828 | 732 | 1.560 | 13.8 | 9.5 | 11.4 |
| October | (8) | 60 | 84 | 144 | 932 | 829 | 1.761 | 15.5 | 9.9 | 12.2 |
| November | (9) | 54 | 50 | 104 | 1.242 | 740 | 1.982 | 23.0 | 14.8 | 19.1 |
| December | (7) | 27 | 29 | 56 | 611 | 496 | 1.107 | 22.6 | 17.1 | 19.8 |
| Totals | (85) | 436 | 569 | 1.005 | 6.596 | 5.462 | 12.058 | 15.1 | 9.6 | 12.0 |




Graph 1. Mortality total flea:mole indices (based on Table II). The horizontal lines represent the annual flea:mole indices ———— = average number of fleas per mole irrespective of the sex of the host; ..... = flea index per male mole; - - - - - - - - = flea index female mole

suddenly begin to show a strong preference for the host's nest or (b) that the majority of them die off during that period.

As *Palaeopsylla minor*, the dominant species in these collections, is a true body-flea and decreases similarly in numbers from May to June, it seems unlikely that the first alternative is the correct explanation of the phenomenon. By the end of May or early June the fleas have apparently gone through their reproductive stage and presumably subsequently perish. The beginning of egg-production would seem to coincide with the onset of the reproductive activities of the host. During the summer months the immature stages of fleas will be found in the nests of the moles, with a relatively low number of adult fleas which survived from the previous year. Towards the autumn fleas begin to emerge from the cocoons and there is a steady rise in the numerosity of fleas on the moles from October onwards; the drop in numbers in January (Graph 1) is very likely not real and doubtless due to the small size of the sample available for that month. The moles are most heavily infested with fleas in March. Presumably this is to be accounted for by the need for fairly constant feeding by fleas during their egg-producing period.

## INFESTATION OF FLEAS PER SEX OF HOST

One of the most interesting as well as unexpected results of this study is the discovery that male moles are considerably more heavily infested with fleas than females, the annual total flea index for the male host being 15.1, that for the female 9.6 (these figures are based on the data pertaining to all moles collected, *i.e.* young and adults).

After the very marked drop in numbers of fleas on the moles from May to June there is no significant difference in infestation of the sexes (*cf.* Table II and Graph 1): during June the female moles actually had a slightly higher flea index, *viz.* 8.6 as against 8.2 for the males. However, from July onwards the numbers of fleas per mole increase gradually; already in this month the male hosts are more heavily infested than females and this discrepancy progresses till February when the average number of fleas on male moles is twice that on females. The difference in infestation between the sexes of host remains at its highest level during February—April and coincides therefore with the reproductive cycle of both host and parasites; the sexual difference in infestation during April (32.5 per ♂ mole, 7.1 per ♀ mole) is very likely too great and due to insufficient samples available for that month (32.5 against 16 or 17 would seem more plausible).

The observed preference of mole-fleas for the male host is as yet difficult to explain. Relatively little pertinent information has been published and, although in only a few of the relevant articles an attempt has been made to explain the phenomenon of disparity in infestation between the sexes of the host, it is nevertheless worthwhile to summarize here the available data.

Gerbils — BAKEYEV et al. (1956) collected 3.220 fleas from 817 specimens of *Meriones tamariscinus* in eastern Ciscaucasia and found that the total flea index for adult male gerbils was 4.8 as against 3.5 for the females. They remark that male gerbils had the greatest number of fleas, especially in springtime when

the males visit a large number of burrows in search of females.

Ground squirrels — Holdenried et al. (1951) report that males (young and adult) of *Citellus beecheyi* had a higher average infestation by fleas than females (young and adult). They based their conclusions on a collection of 63.907 fleas taken from 2.321 ground squirrels in California during a period of 3½ years and surmise that "Skin and hair conditions of the male ground squirrel may be more favorable for flea feeding, so that the parasites would remain longer on this sex than on the female and thus larger numbers would accumulate. It is also possible that after family groups have broken up and the various individuals have taken up separate burrows and nests the ecological conditions surrounding the males might favor larger flea numbers. Greater mobility on the part of the males, which was observed in the young squirrels but not in the adults, would also facilitate the acquisition of larger numbers of fleas."

Parker (1958) obtained 2.715 fleas from 138 *Citellus leucurus leucurus* during 12 months live trapping in Utah. He found an average of 17.8 fleas per ♂ squirrel (93% of males infested) and 15.7 fleas per ♀ squirrel (86% of females infested) and remarks that The ratio of infestation of the two sexes remained relatively constant seasonwise" and that "The significance of these observations is not known, even though the findings corroborate results from investigations reported by Holdenried et al. (1951)."

Rats — Eskey (1934) collected fleas from 20.000 rats in the Hawaiian islands during a period of twelve months and states that "... adult males [of rats] were more infested [with *Echidnophaga gallinacea*] than females, while *Xenopsylla cheopis* ... were more prevalent on females than on males."

Roberts (1936) found that in Kenya the index of *Xenopsylla brasiliensis* on male *Rattus rattus* was 2.7 as against 2.6 for the female; this is based on 18.074 fleas from 6915 rats collected over a whole year. "The average number of *X. brasiliensis* on male and female rats does not show that females are liable to heavier infestations even during the period when birth-rates are highest." Note, however, that there was "a very decided dominance of females (73%) to males in the *Rattus* population, a superiority which was maintained in each month."

Roberts (1939) reporting on two years collecting, also in Kenya, obtained a similar flea index for rats, viz., male rats with an average of 2.9 fleas, female rats with 2.7.

Morlan & Utterback (1952) trapped 16.363 *R. rattus* and 4.123 *R.norvegicus* in Georgia, U.S.A., over a period of 3 years and state that "conclusive differences in percentages of male and female rats infested with *X. cheopis* and *L. segnis* in the different counties, years, and species [of rat] were not apparent."

Mice — George (1959) found that on St. Kilda the flea index for adult male "mice" (presumably *Apodemus sylvaticus hirtensis*) was 4.3 as against 1.5 for adult females; the infestation rate of male mice was also higher: 81% of male mice were flea-infested, 46% of the female mice.

George & Corbet (1959), analysing flea-collections made in Scotland, show that both juvenile and adult males of *Microtus agrestis, Clethrionomys glareolus, Apodemus sylvaticus*, and *Sorex araneus* are on the whole considerably more heavily infested with fleas than females. They refer to Buxton (1948) who stated that it is probable that a mammalian sex hormone is necessary for full

reproductive development of fleas; "This in itself would be a contributory explanation of the higher index for adults (with the modifying factor that more fleas are eaten by adult than by immature hosts, as was shown for mice by BUXTON, l.c.), but if the sex hormone concerned is an androgen the higher index of males could be explained."

The above evidence shows that on the whole the male host tends to be more heavily infested with fleas than the female host, but a satisfactory explanation has not been brought forward. BUXTON's suggestion (1948) that the host's sex hormone may be required to stimulate sexual maturation in the female flea seems to make sense if, as remarked by GEORGE & CORBET (1959), androgen is needed rather than oestrogen. MEAD-BRIGGS & RUDGE (1960) fed rabbit fleas (*Spilopsyllus cuniculi*) on pregnant and non-pregnant does and concluded that this flea requires a pregnant host for egg maturation, but it should be noted that these authors have apparently not used bucks in their experiments.

BUXTON (1948), experimenting with *Xenopsylla cheopis* on baby and adult white mice, concludes that "as far as life is concerned the baby mouse is an excellent host for *X. cheopis*" ... "But it is equally clear that fleas fed on the baby mouse tend to produce an abnormally low number of eggs per day and to start laying after an unusual interval." BUXTON then suggests that a mammalian sex hormone may be required by the flea at least to induce normal egg production.

DE MEILLON & HARDY (1951) repeated BUXTON's experiments, but with *Cimex lectularius* on white mice of various age groups. They found that by feeding the bugs on baby mice the egg production decreased, but no difference in numbers of eggs laid was detected when the bugs were fed on mice of 10 days old and over or when fed on adult mice. The authors remark "it seems scarcely likely that at the age of ten days there will be sufficient sex hormones in circulation to affect the issue" and they suggest that, as the blood of newborn animals differs in many respects from that of adults, "it seems, therefore, that substances which inhibit egg production are produced or liberated in haemolysed blood [of the baby host]."

Whether or not a flea needs a sex hormone from either the male or female host, the fact remains that on the whole the male host appears to be favoured by fleas. How does a flea discriminate between the sexes of a host? Either the characteristics of the male host's body attract fleas more than those of the female's, or the male's mode of life brings him in greater contact with fleas than that of the female would.

In the European mole there is virtually no sexual difference in the pelage but Jhr. VAN HEURN informs me that the males are larger and on an average $^5/_4$th as heavy as females. This implies that the flea-holding capacity of males is larger than that of females, but as the ratio of body surface of male: female = 6 : 5 (approximately) this would not explain the very marked preponderance of fleas on the male host animal. As for ecological differences between the sexes of the mole, it appears that the nests of males and females are similar, but females especially may have several nests in use simultaneously (GODFREY & CROWCROFT, 1960). As the male mole keeps more to one nest, the fleas are more concentrated and more regularly in contact with the male host than is the case with the female mole. The male mole therefore creates an environment in which fleas can doubt-

less thrive better than in that furnished by the female. Whether or not hormones or other substances from either the male or the female host are required to induce breeding on the part of the fleas remains to be investigated; as the preponderance of fleas on the male host is not confined to the fleas' breeding cycle it would seem more likely that ecological factors are in the first place responsible for the popularity of males.

It should be noted that adult male and female moles live as two entirely separate entities — they have their own territories and nests and the only contact between the sexes, apart from occasional fighting to preserve the isolation and territorial rights of the individuals, occurs during a courtship of only a few minutes and the act of copulation which is of unknown duration and takes place only once a year (February-March) (Godfrey & Crowcroft, 1960). There are consequently hardly any opportunities for the fleas to go over to a host individual of opposite sex; in any case such an exchange would not be on a scale of any significance. It is therefore obvious that the male mole creates a more favourable environment for fleas than females.

## Degree of infestation of juvenile and adult moles

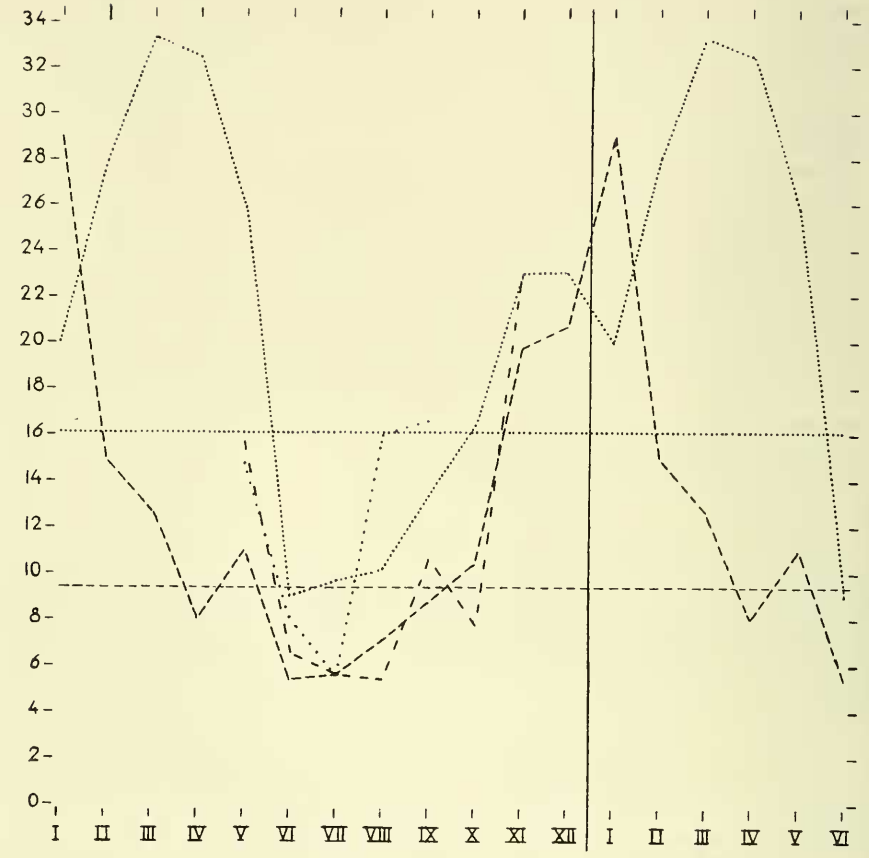
As is mentioned in the introduction, Jhr. van Heurn recorded the age-group and sex for almost every mole caught. Table III gives the flea indices for young and adult males and females; a number of females were recorded as "virgo", but these have been omitted from Table III since the age of such specimens is not known.

Table III

| 1950--1960 | Juvenile moles | | | | | | Adult moles | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ♂ | | | ♀ | | | ♂ | | | ♀ | | |
| | No. | Fleas | Flea index | No. | Fleas | Flea index | No. | Fleas | Flea index | No. | Fleas | Flea index |
| Jan. | | | | | | | 1 | 20 | 20.0 | 1 | 29 | 29.0 |
| Febr. | | | | | | | 4 | 112 | 28.0 | 4 | 60 | 15.0 |
| March | | | | | | | 9 | 300 | 33.3 | 6 | 76 | 12.7 |
| April | | | | | | | 10 | 325 | 32.5 | 7 | 57 | 8.1 |
| May | 4 | 59 | 14.8 | 4 | 63 | 15.7 | 13 | 337 | 25.9 | 6 | 66 | 11.0 |
| June | 10 | 81 | 8.1 | 52 | 344 | 6.6 | 26 | 235 | 9.0 | 14 | 75 | 5.4 |
| July | 7 | 39 | 5.6 | 33 | 188 | 5.7 | 50 | 486 | 9.7 | 26 | 146 | 5.6 |
| Aug. | 5 | 80 | 16.0 | 43 | 234 | 5.4 | 56 | 570 | 10.2 | 16 | 114 | 7.1 |
| Sept. | 5 | 83 | 16.6 | 30 | 318 | 10.6 | 45 | 599 | 13.3 | 11 | 96 | 8.7 |
| Oct. | | | | 16 | 125 | 7.8 | 48 | 787 | 16.4 | 7 | 73 | 10.4 |
| Nov. | | | | 6 | 137 | 22.8 | 46 | 1.057 | 23.0 | 8 | 158 | 19.7 |
| Dec. | | | | | | | 21 | 486 | 23.1 | 4 | 83 | 20.7 |
| Totals | 31 | 342 | 11 | 184 | 1.409 | 7.7 | 329 | 5.314 | 16.1 | 110 | 1.033 | 9.4 |

As can be seen from Table III and from the graph based upon this Table (Graph 2), young moles are less heavily infested with fleas than are adults. As for the adults, we see that the difference in the annual total flea index between the sexes is even greater (*i.e.* 16.1 for ♂, 9.4 for ♀) than that given in Table II in which moles of all ages are considered together (*i.e.* 15.1 for ♂, 9.6 for ♀).

Here again there are not many pertinent data available in the literature; the following particulars are known to me.




Graph. 2. Monthly total flea:mole indices for adult and juvenile moles (based on Table III). The horizontal lines represent the annual flea:mole indices ..... = per adult male mole. . . . . = per juvenile male mole; - - - - - - - - - = per adult female mole; — — — — — — = per juvenile female mole

Moles.

DARSKAYA (1953) collected in the Mikhnevo district of the Moscow province during June—September (but mostly in July) 132 moles, nearly all juveniles, which yielded only 213 fleas — flea index: 1.6. Unfortunately no comparison was here possible with the flea index of adult moles from the same district.

Pikas.

DARSKAYA (1957) mentions that in southeast Transbaikalia the average number of fleas on adult pikas (*Ochotona daurica*) was 3.4 and 3.5 respectively in June and July, while on young pikas it was 2.6 and 2.7 respectively.

Gerbils.

BAKEYEV et al. (1956), in dealing with the ectoparasites of *Meriones tamariscinus* in eastern Ciscaucasia, give the flea index for adult males as 4.8, for adult

females as 3.5 and for young gerbils as 0.4! The authors remark that the low flea index for juvenile gerbils can probably be explained by the lesser activity of the young in visiting burrows, and they are therefore less liable to attract hungry fleas than adults which rove about much more.

Rats.

Eskey (1934) states that in the Hawaiian islands "young rats were rarely found infested with *Echidnophaga gallinacea* ..... while *Xenopsylla cheopis* were somewhat more prevalent on young rats than on adults..."

The latter statement is confirmed by Morlan & Utterback (1952) who remark about their findings in Georgia, U.S.A.: "The data indicate that normally *X. cheopis* infests young rats more frequently than adult rats" and "more frequent infestation of young than adult rats might be expected because of a more constant contact of young rats with infested nest material"; further "If all counties and years are considered, infestations of *Leptopsylla segnis* were similar on adult and young rats, and the differences observed showed no apparent pattern."

The above evidence, meagre as it is, indicates that only in certain host animals or only in relation to certain species of fleas the flea index for the juveniles may be lower than that for the adult hosts.

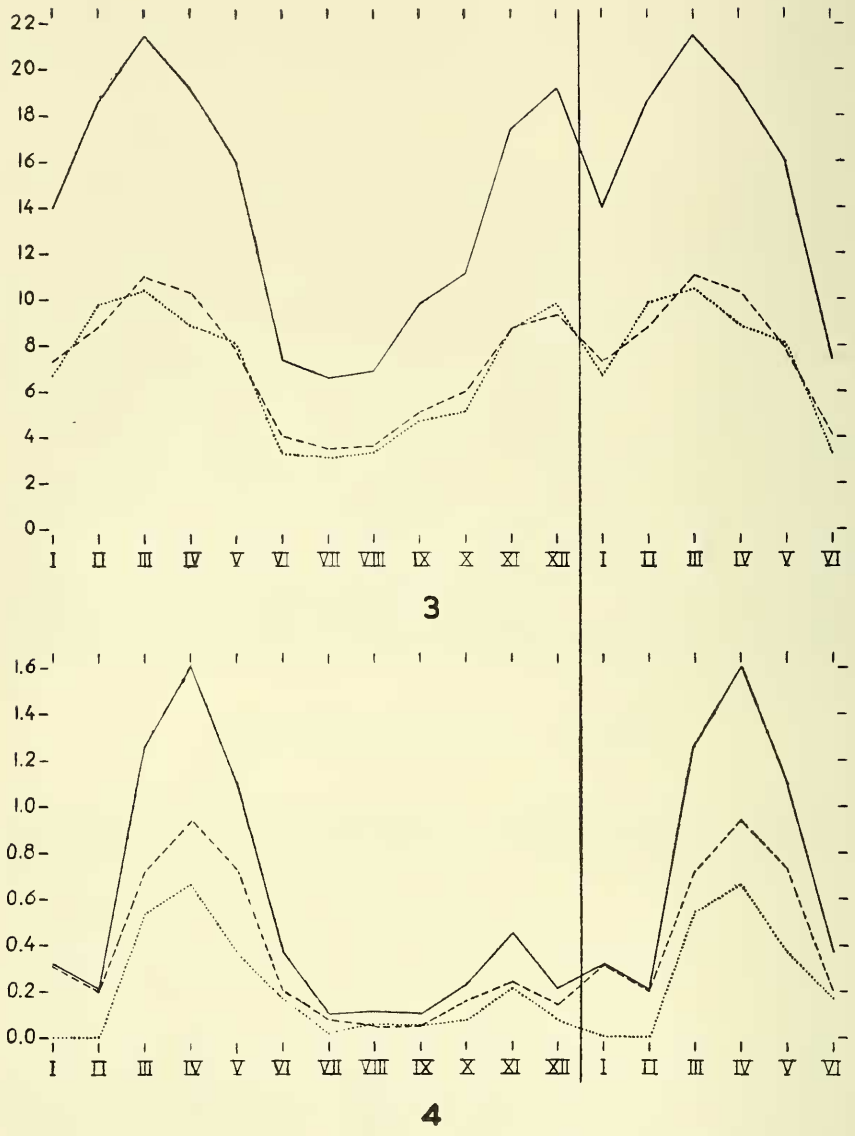
In the case of the mole the explanation seems simple; the fleas are mostly in immature stages during the juvenile stage of the host. Young moles grow very rapidly and are fully grown towards the autumn when the mass emergence of fleas from the cocoons would set in.

## Monthly specific flea:mole indices

The data concerning the monthly flea indices for the two monoxenous species of mole-fleas (*Palaeopsylla minor* and *Ctenophthalmus bisoctodentatus heselhausi*) are given in Table IV and the figures of the flea:mole indices are shown

Table iv

| Months | *P. minor* | | | | | | *C. bisoctodentatus heselhausi* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of specimens | | | Flea:mole index | | | No. of specimens | | | Flea:mole index | | |
| | ♂ | ♀ | total | ♂ | ♀ | total | ♂ | ♀ | total | ♂ | ♀ | total |
| Jan. | 40 | 44 | 84 | 6.7 | 7.3 | 14.0 | 0 | 2 | 2 | 0 | 0.31 | 0.31 |
| Febr. | 98 | 88 | 186 | 9.8 | 8.8 | 18.6 | 0 | 2 | 2 | 0 | 0.20 | 0.20 |
| March | 229 | 243 | 472 | 10.4 | 11.0 | 21.4 | 12 | 16 | 28 | 0.54 | 0.72 | 1.26 |
| April | 160 | 185 | 345 | 8.9 | 10.3 | 19.2 | 12 | 17 | 29 | 0.66 | 0.94 | 1.60 |
| May | 243 | 238 | 481 | 8.1 | 7.9 | 16.0 | 11 | 22 | 33 | 0.37 | 0.73 | 1.10 |
| June | 431 | 540 | 971 | 3.3 | 4.1 | 7.4 | 23 | 26 | 49 | 0.17 | 0.20 | 0.37 |
| July | 517 | 600 | 1.117 | 3.1 | 3.5 | 6.6 | 4 | 12 | 16 | 0.02 | 0.08 | 0.10 |
| Aug. | 583 | 646 | 1.229 | 3.3 | 3.6 | 6.9 | 11 | 10 | 21 | 0.06 | 0.05 | 0.11 |
| Sept. | 654 | 729 | 1.383 | 4.7 | 5.1 | 9.8 | 9 | 9 | 18 | 0.05 | 0.05 | 0.10 |
| Oct. | 736 | 862 | 1.598 | 5.1 | 6.0 | 11.1 | 11 | 23 | 34 | 0.07 | 0.16 | 0.23 |
| Nov. | 902 | 910 | 1.812 | 8.7 | 8.7 | 17.4 | 22 | 25 | 47 | 0.21 | 0.24 | 0.45 |
| Dec. | 541 | 515 | 1.056 | 9.8 | 9.3 | 19.1 | 4 | 8 | 12 | 0.07 | 0.14 | 0.21 |
| Totals | 5.134 | 5.600 | 10.734 | 5.1 | 5.6 | 10.7 | 119 | 172 | 291 | 0.12 | 0.17 | 0.29 |




Graphs 3, 4. Monthly specific flea:mole indices (based on Table IV). 3. *Palaeopsylla minor*; 4. *Ctenophthalmus bisoctodentatus heselhausi*. ———— = male and female fleas together; ..... = male fleas; - - - - - - - - - = female fleas

in graphs (Graphs 3, 4). *P. minor* occurs in western and Central Europe, *C. bisoctodentatus heselhausi* in north-west Europe and the nominate subspecies in the remainder of Europe north of latitude 44.

As will be seen from Graphs 3 and 4, the curves are similar for the two species and — as was to be expected since *P. minor* is the predominant species — agree with the one shown in Graph 1.

The sex-ratio of *P. minor* shows only a slight excess of females, but in *C. b. heselhausi* the females outnumbered the males by almost three to two.

Table V and Graphs 5 and 6 show similar data for the two commonest non mole-specific fleas *C. agyrtes smitianus* and *H. talpae talpae*; in the former species there is a considerable excess of females over males, the ratio being 5 : 3, but in the latter species the males were slightly more numerous.

*C. agyrtes smitianus* is found from the Netherlands (except in the northernmost provinces) through southern Germany to north-east Austria; other subspecies occur in the remainder of Europe.

*H. talpae talpae* is the subspecies in northwest Europe, while *H. t. orientalis* occurs in the rest of Europa (except the Iberian Peninsula) and extending eastward to the Krasnoyarsk region of the USSR and south to the Altai, Tyan-Shan and Caucasus Mts.

Table v

| Months | *C. agyrtes smitianus* | | | | | | *H. talpae talpae* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of specimens | | | Flea:mole index | | | No. of specimens | | | Flea:mole index | | |
| | ♂ | ♀ | total | ♂ | ♀ | total | ♂ | ♀ | total | ♂ | ♀ | total |
| Jan. | 6 | 6 | 12 | 1.00 | 1.00 | 2.00 | 1 | 2 | 3 | 0.17 | 0.33 | 0.50 |
| Febr. | 6 | 3 | 9 | 0.60 | 0.30 | 0.90 | 0 | 0 | 0 | 0 | 0 | 0 |
| March | 17 | 18 | 35 | 0.77 | 0.82 | 1.59 | 1 | 2 | 3 | 0.05 | 0.09 | 0.14 |
| April | 2 | 3 | 5 | 0.11 | 0.16 | 0.27 | 1 | 1 | 2 | 0.05 | 0.05 | 0.10 |
| May | 14 | 25 | 39 | 0.47 | 0.83 | 1.30 | 0 | 1 | 1 | 0 | 0.03 | 0.03 |
| June | 27 | 62 | 89 | 0.20 | 0.47 | 0.67 | 3 | 4 | 7 | 0.02 | 0.03 | 0.05 |
| July | 74 | 102 | 176 | 0.44 | 0.60 | 1.04 | 1 | 0 | 1 | 0.01 | 0 | 0.01 |
| Aug. | 61 | 100 | 161 | 0.34 | 0.56 | 0.90 | 4 | 10 | 14 | 0.02 | 0.06 | 0.08 |
| Sept. | 43 | 71 | 114 | 0.31 | 0.52 | 0.83 | 18 | 17 | 35 | 0.13 | 0.13 | 0.26 |
| Oct. | 23 | 63 | 86 | 0.16 | 0.44 | 0.60 | 24 | 17 | 41 | 0.16 | 0.12 | 0.28 |
| Nov. | 27 | 42 | 69 | 0.26 | 0.40 | 0.66 | 27 | 21 | 48 | 0.26 | 0.20 | 0.46 |
| Dec. | 12 | 19 | 31 | 0.21 | 0.34 | 0.55 | 4 | 2 | 6 | 0.07 | 0.04 | 0.11 |
| Totals | 312 | 514 | 826 | 0.31 | 0.51 | 0.82 | 84 | 77 | 161 | 0.08 | 0.08 | 0.16 |

## The accidental occurrence on moles of some species of fleas

Among the 12.058 fleas collected from the bodies of moles are 46 specimens (0.39%) belonging to four different species which are in no way associated with the mole. This is an indication that their hosts occasionally cross the 'paths' of moles by using their tunnels or runs where they may even experience the mole's agressive habits. The following stray species have been collected:

14 ♂ 12 ♀ *Palaeopsylla soricis soricis* — this is a very common parasite of shrews in Europa and Asia (east to Tyan-Shan, Altai Mts. and western Transbaikalia); the nominate subspecies is confined to western Europe.

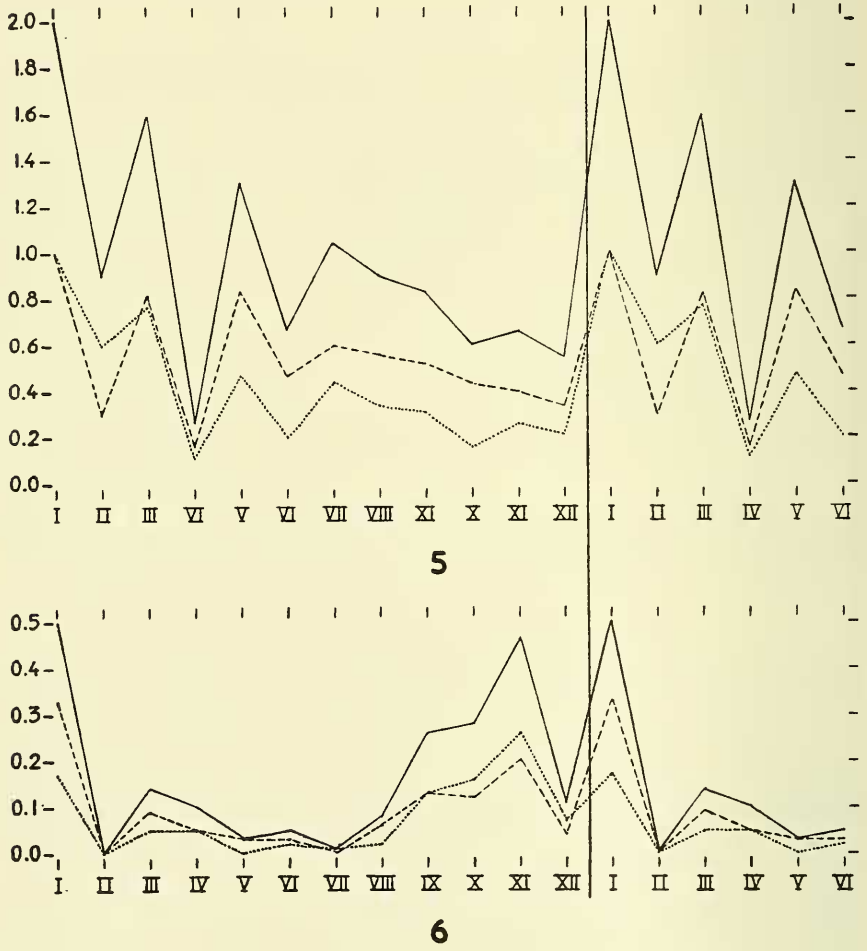
2 ♂ 4 ♀ *Doratopsylla dasycnema dasycnema* — likewise a specific parasite of shrews in Europa and western USSR which shows a preference for hosts living in a wooded habitat; another subspecies occurs in the Mediterranean subregion.

6 ♂ 4 ♀ *Malaraeus penicilliger mustelae* — this flea is primarily associated with *Clethrionomys glareolus*, although species of *Microtus* are often suitable

secondary hosts. On the estate where the moles were collected this is quite a common flea on the bank vole, but it has so far been collected nowhere else in the Netherlands. In Great Britain it is a common flea everywhere. The species *M. penicilliger* occurs throughout the European and Siberian subregions of the Palaearctic region.

4 ♂ *Megabothris turbidus* — a common flea of *Clethrionomys glareolus* and *Apodemus sylvaticus*, occurring in most of Europe and in the USSR east to Transbaikalia and Altai Mts. and south to the Caucasus.

As shrews are certainly not more heavily infested with fleas than voles or mice, we may deduce from the above data that either shrews make greater use of the mole's tunnel system than do voles and mice or that strayed shrew-fleas are




Graphs 5, 6. Monthly specific flea:mole indices (based on Table V). 5. *Ctenophthalmus agyrtes smitianus*; 6. *Hystrichopsylla talpae talpae*. ———— = male and female fleas together; ..... = male fleas; - - - - - - - - = female fleas

more strongly attracted by moles (which have a pelage not markedly unlike that of shrews) than rodent-fleas are.

In the nests of moles stray fleas were of even rarer occurrence: excluding the 31 bird-fleas (*Ceratophyllus gallinae*) only 2 stray specimens were found among the total of 1.241 fleas collected from 45 nests (0.16%). They belong to the following species:

1 ♀ *Megabothris turbidus* — see above.

1 ♂ *Ctenophthalmus assimilis* — primarily a parasite of *Microtus arvalis*, but other Microtines can serve as a secondary host. Where moles live in meadows which are also populated by *Microtus arvalis*, this species of flea is usually extremely common in moles' nests which must therefore suit the flea ecologically. That only one specimen of *C. assimilis* was found among the 13.330 fleas strongly indicates that *Microtus arvalis* is absent from the estate "Kleine Noordijk" and indeed, Jhr. van Heurn confirmed this. I have trapped many bank voles in the area concerned and found *C. assimilis* only very sporadically. In a mole's nest collected in a meadow where *Microtus arvalis* occurs, a few miles away from the trapping area, I found seven specimens of *C. assimilis* among the 38 fleas collected.

To find 20 ♂ 11 ♀ *Ceratophyllus gallinae* in a mole's nest would at first sight defy explanation. This is the commonest bird-flea throughout Europe and in Asia to the Caucasus and western Siberia; it prefers relatively dry nests in shrubs or in trees and is the common flea of poultry, often becoming a real pest in hen-houses (it is called the European chicken-flea). Here we have the simple explanation: Jhr. van Heurn, a great advocate of full and careful labelling, wrote on the label for the fleas which he collected from a mole's nest on 17.XI. 1954 that guano from hen-houses as well as manure had been applied to the land. Numerous chicken fleas must have been emerging from the chicken guano and taken with nesting material by the moles who do surface occasionally to collect dry leaves and grass for lining their nests; of course the moles themselves may also have attracted the fleas.

Heselhaus (1913b) recorded *C. gallinae* from a mole's nest from Valkenburg (Limburg, Netherlands) but without any specifications.

## The flea population of moles' nests in comparison with that of the moles

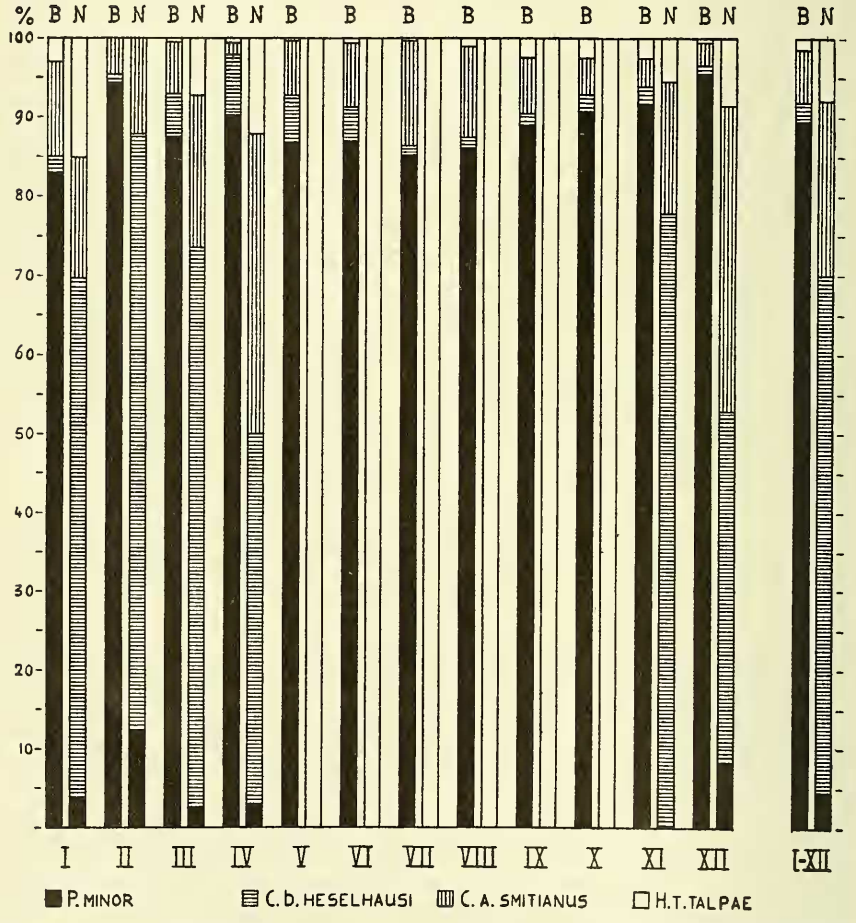
The numbers and species of fleas collected by Jhr. van Heurn from 45 nests are given in Table I.

A comparison of the percentages of the species composition for the four main species of fleas is given in Table VI, while Graph 7 is based upon the data from this Table.

From Table VI and Graph 7 emerges the interesting fact that *Palaeopsylla minor* is by far the dominant species on the body of the host, while in the nest *Ctenophthalmus bisoctodentatus heselhausi* clearly dominates; the former proves therefore to be a true body-flea, the latter a nest-flea. *Ctenophthalmus agyrtes smitianus* and *Hystrichopsylla talpae talpae* are also nest-fleas, but to a lesser degree.

TABLE VI

| 1950—1960 | *P. minor* | | *C. b. heselhausi* | | *C. a. smitianus* | | *H. t. talpae* | |
|---|---|---|---|---|---|---|---|---|
| | Body | Nest | Body | Nest | Body | Nest | Body | Nest |
| Jan. | 83.1 | 3.8 | 2.0 | 65.9 | 11.9 | 15.1 | 3.0 | 15.1 |
| Febr. | 94.4 | 12.4 | 1.0 | 75.9 | 4.6 | 11.7 | 0 | 0 |
| March | 87.7 | 2.7 | 5.2 | 70.9 | 6.5 | 19.2 | 0.5 | 7.2 |
| April | 90.3 | 3.0 | 7.6 | 47.0 | 1.3 | 37.9 | 0.6 | 12.1 |
| May | 86.8 | | 5.9 | | 7.1 | | 0.2 | |
| June | 87.0 | | 4.4 | | 8.0 | | 0.6 | |
| July | 85.3 | | 1.2 | | 13.4 | | 0.1 | |
| Aug. | 86.2 | | 1.5 | | 11.3 | | 1.0 | |
| Sept. | 89.2 | | 1.2 | | 7.3 | | 2.3 | |
| Oct. | 90.8 | | 2.0 | | 4.9 | | 2.3 | |
| Nov. | 91.7 | 0.3 | 2.4 | 77.6 | 3.5 | 13.3 | 2.4 | 5.7 |
| Dec. | 95.6 | 8.4 | 1.1 | 44.9 | 2.8 | 38.3 | 0.5 | 8.4 |
| Whole year | 89.4 | 4.6 | 2.4 | 65.5 | 6.9 | 22.1 | 1.3 | 7.8 |




Graph 7. Percentages of the species composition for the four main species of mole-fleas on body of moles (B) and in nests of moles (N) (based on Table VI)

Very few detailed data have been published on the flea-fauna of moles' nests. Wagner (1936) states that in a collection of over 2.000 fleas, made from an unrecorded number of moles' nests in the neighbourhood of Vienna, during winter months, the dominant species was *Ctenophthalmus assimilis* (1500 ♂ ♀) — *Microtus arvalis* must have been common in the areas where the nests were collected; *Ctenophthalmus agyrtes* accounted for 310 specimens, *C. bisoctodentatus* for 302 and *Hystrichopsylla talpae* for 44, while *Palaeopsylla similis* (a specific mole-flea like *P. minor*) numbered only 15 (there were also 31 specimens, belonging to five species, which occurred accidentally in the nests). Wagner further remarks that *P. similis* was absent in many nests. It is clear, therefore, that *P. similis* is a true body-flea like *P. minor*.

Rosický (1957) examined 16.612 fleas from 234 moles' nests (an average of 71 fleas per nest) in Czechoslovakia. He gives an interesting comparison of the species composition in nests in five different biotopes and the following Table VII is based on Rosický's Table 6 and on figures from his summary (the figures for the species are percentages). The author points out that moles in fields and meadows were living side by side with *Microtus arvalis* which explains the large numbers of *C. assimilis*.

Table vii

| Nest in : | *P. similis* | *C. bisoctodentatus* | *C. agyrtes* | *C. assimilis* | *H. talpae* | Other species | Average number of fleas per nest |
|---|---|---|---|---|---|---|---|
| Fields | 0 | 15.20 | 0.46 | 83.40 | 0.60 | 0.34 | 81.5 |
| Meadows | 0.04 | 11.10 | 0.57 | 86.80 | 1.01 | 0.48 | 70.9 |
| Scrub | 0.30 | 17.70 | 7.90 | 70.83 | 1.75 | 1.52 | 65.6 |
| Edge of woods and open spaces in woods | 0.90 | 26.30 | 9.80 | 56.30 | 3.90 | 2.80 | 81.1 |
| Woods | 5.70 | 20.40 | 29.00 | 35.10 | 1.30 | 8.50 | 46.6 |

## General remarks

(*a*) Of the 1.005 moles collected, 51 (16 ♂ 35 ♀), or 5%, were without fleas. The rate of infestation can therefore be considered to be very high and the above figures (16 ♂ 35 ♀) also agree with the fact that male moles are more heavily infested than females.

(*b*) As the moles were not fumigated prior to the removal of ectoparasites, dead fleas came to light occasionally. In all, 10 ♂ moles had 17 dead fleas and 5 ♀ moles had 5 dead ones. Once again we see that the average per male host is higher than that of the female. Whether these fleas had died a natural death or, as is just possible, had been hit by the metal bar of the trap remains unanswered.

(*c*) The highest number of fleas on a male mole was 78 (February 1957), on a female (paradoxically) 188 (June 1950).

(*d*) Taking all fleas collected into account, their sex-ratio on the body of the

moles was 47% ♂ 53% ♀ and in the nests 38% ♂ 62% ♀. In both instances there is an excess of females, but this is very pronounced in the nests; it indicates that the female fleas spend more time in the nests than the males do.

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